Disk Drive With Read While Write Capability

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Field of the Invention

The present invention related generally to disk drives and in particular to read/write preamplifiers for disk drives.

Background of the Invention

Data storage systems such as disk drives are utilized for data storage and retrieval in a variety of applications. A typical disk drive includes a spindle motor for rotating a data disk, and an actuator for moving a head carrier that supports transducer (read/write) heads radially across the disk to write data to or read data from concentric data tracks on the disk. Many disk drives include a plurality of disks separated by spacer rings and stacked on a hub attached to the spindle motor, a plurality of read/write heads, and a plurality of head carriers, each head carrier supporting at least one read/write head. To access a data segment starting on a track, in a seek operation the head is moved radially across the tracks to the desired track where the data segment starts. Thereafter, the rotation of the disk rotates the data segment on the track under the head for writing data to or reading data therefrom.

The disk drive further includes a preamplifier electrically connected to the heads. During operation of the disk drive, the preamplifier provides two mutually exclusive functional data transfer modes: a write mode, wherein data is transmitted to the preamplifier via a write data input and is subsequently recorded to the data disk in a write operation via a head; and read mode, wherein magnetic signals sensed by a head subsequently undergo signal processing within the preamplifier before output from the preamplifier.

Because the read and write functions are mutually exclusive, conventional disk drives suffer from timing constraints which limit the disk drive□s signal handling. These limitations directly effect several functions and processes common to most disk drive devices. For example, the mutually exclusive preamplifier does not allow the disk drive to: (1) perform self-servo writing with an absolute timing and position reference by reading a reference pattern from one surface while writing a servo pattern to another surface, (2) reprocess (erase) a previously written data disk without the need for an external positioning device or time consuming algorithms, by reading on one head while writing an erase pattern on one more heads at the same time, (3) perform efficient tests for high density data disks to reduce test time by reading while writing data, (4) increase data write accuracy by effectively adjusting for head positioning errors due to disk flapping modes that cause unwanted disturbances, (5) increase data read accuracy and efficiency by reading head position information and track centering on one head while writing with another head on another surface, etc.

In servo writing, servo patterns are typically written with uniform angular spacing of servo sectors and interleaved data sectors or blocks. An example servo pattern includes circumferentially sequential, radially staggered single or multiple frequency bursts. Servo patterns provide the disk drive with head position information to enable the actuator, such as a rotary voice coil positioner, to move the head from starting tracks to destination tracks during random access track seeking operations. Further, the servo patterns provide the disk drive with head position information to enable the actuator to position and maintain the head in proper alignment with a track centerline during track following operations when user data is written to or read from the available data block storage areas in concentric data tracks on the disk surface.

Conventionally servo patterns are written into the servo sectors of each disk using a servo writer at a point in the drive assembly process before the hard disk unit is sealed against particulate contamination from the ambient. A servo writer is a complex and

expensive manufacturing unit, typically stabilized on a large granite base to minimize unwanted vibration and employing e.g. laser interferometry for precise position measurements. The servo writer typically requires direct mechanical access to the head arm, and includes a fixed head for writing a clock track onto a disk surface.

Because of the need for direct access to the interior of the hard disk assembly of each disk drive unit, the servo writer is typically located within a clean room where the air is purged of impurities that might otherwise interfere with operation including the servo writing process or in normal usage after manufacturing. Further, such conventional servo-writing methods are very time consuming. In one example, a disk drive having two disks with four data storage surfaces can require three servo-writer-controlled passes of the transducer head over a single track during servo writing, consuming a total servo writing time as long as 18.2 minutes. Thus, servo writing using servo writers in clean rooms requires both considerable capital investment in the manufacturing process and severe time penalties in the manufacturing process attributable to servo writer bottlenecks. Further, as track densities increase with evolving hard disk designs, servo writers become obsolete, and have to be replaced, or upgraded, at considerable capital expense.

To solve the above problems, another conventional method is directed to servo writing a master pattern at full resolution on one surface of a master disk during a pre-assembly operation. Then, a master disk with the master pattern is assembled with other blank disks into a disk drive unit. After the disk drive unit is sealed against the ambient, the master servo pattern of the master disk is used as a reference by the disk unit in self-writing embedded sector servo patterns on each data surface within the enclosed unit. Finally, the master pattern is erased, leaving the disk drive unit with properly located embedded servo sector patterns on every surface, including the surface which originally included the master pattern. However, such a method had several disadvantages: (1) servo-writing time is very long, (2) certain repeatable run out information must be removed during the self-servo write operation; (3) a number of expensive servo writers are still required to write the master patterns on the master disks; and (4) and no absolute reference from the reference disk is

available during servo writes to a blank disk since read and write operations are mutually exclusive and possible defects in the printed media can exacerbate the problem, etc..

There is, therefore, a need for a storage device, such as a disk drive, with simultaneous read and write capability. There is also a need for a self-servo write method utilizing simultaneous read and write to alleviate the above problems, and provide a means to cost effectively enhance storage device manufacturing and performance.

Brief Summary of the Invention

The present invention alleviates the aforementioned shortcomings. In one embodiment, the present invention provides a data transfer driver comprising a preamplifier for a disk drive including recording media having one or more recording surfaces, one or more data transducer heads positionable relative to the recording surfaces by a head position actuator structure operating within a head position servo loop. The preamplifier comprises: a control interface for receiving preamplifier configuration information to selectively transfer data to and from recording surfaces; one or more head interfaces, each head interface electrically connected to a transducer head for controlling the transducer head for data read and/or write operations; and a controller electrically connected to the control interface and to each head interface, for controlling the operation of each head interface based on the configuration information for selectively reading from at least one recording surface via at least one transducer head while writing data to at least one recording surface via at least one transducer head. Further, the preamplifier can be used for separately writing data to at least one recording surface and/or reading data from at least one recording surface.

In another aspect, the present invention provides a method for self-servo writing a disk drive by first transferring a servo reference pattern to a recording surface of a reference disk, wherein the reference pattern comprises servo clock information providing transducer head circumferential relative position information, and servo position information providing transducer head radial relative position information. Thereafter, the disk drive is assembled

by installing the reference disk and one or more data disks into the disk drive and enclosing the disks and data transducers within a housing. For self-servo writing, the reference pattern is read from the reference disk via a head, and using the read servo clock and the servo position information one or more heads are positioned and maintained at concentric track locations of one or more data disk recording surfaces to simultaneously write disk drive servo patterns onto the recording surfaces.

Conventionally, reading a reference pattern from the disk surface via a read head is sequentially followed by switching to other heads to write a servo pattern on data disks, wherein the read and write operations are mutually exclusive (i.e., not overlapping or simultaneous). The conventional self-servo write process switches between reading and writing until the entire servo pattern is written out on a disk. However, according to the present invention there is no need to switch out of the reference pattern to write servo patterns on data disks. The reference information (e.g., timing and position information) obtained from the reference disk via one head is used to simultaneously clock out servo patterns to other data disks on other heads.

Brief Description of the Drawings

These and other features, aspects and advantages of the present invention will become understood with reference to the following description, appended claims and accompanying figures where:

FIG. 1 shows a block diagram of the architecture of an embodiment of a computer system including a disk storage system according to an aspect of the present invention;

FIG. 2 shows an example block diagram of the architecture of an embodiment of the drive electronics of disk drive of FIG. 1 according to the present invention;

FIG. 3 shows a more detailed block diagram of the drive electronics of FIG. 2;

FIG. 4 shows an example block diagram of an embodiment of a preamplifier circuit of FIG. 3 showing example read head and write head selection circuitry according to the present invention;

FIG. 5 shows an example block diagram of another embodiment of the preamplifier

circuit of FIG. 3 showing example read head and write head selection circuitry according to the present invention;

FIG. 6 shows a highly diagrammatic representation of an embodiment of a magnetic printing station for printing a reference disk storage surface with a servo reference pattern;

FIG. 7 shows a diagrammatic representation of an embodiment of a disk drive including a disk with a servo reference pattern according to the present invention; and

FIG. 8 shows an example functional diagram of self-servo writing according to an aspect of the present invention;

FIG. 9A-B shows an example flow diagram of self-servo writing according to the present invention;

FIG. 10A shows an example reference pattern according to the present invention;

FIG. 10B shows an example flow diagram of head position control while self-servo writing using the reference pattern of FIG. 10A;

FIG. 10C shows a details of a portion of the reference pattern of FIG. 10A;

FIG. 11 shows an example diagram for generating a final servo patterns according to the present invention;

FIG. 12 shows an example flow diagram for writing final servo patterns according to the present invention; and

FIG. 13 shows an example flow diagram of reprocessing according to the present invention.

To facilitate understanding, identical reference numerals have been used, where possible, to designate structurally/functionally identical or similar elements that are common throughout the figures.

Description of the Invention

Referring to FIG. 1, an example computer system 10 is shown to include a disk storage unit according to the present invention. The computer system 10 includes a central processing unit ("CPU") 14; a main memory 16, and I/O bus adapter 18, all interconnected by a system bus 20. Coupled to the I/O bus adapter 18 is an I/O bus 22 that can comprise

e.g. a small computer system interconnect (SCSI) bus, and which supports various peripheral devices 24 including a disk storage unit such as a disk drive 25. The disk drive 25 includes drive controller electronics 26 and a head disk assembly 28 ("HDA"). As shown in FIG . 7, in one embodiment, the HDA 28 includes data disks 29 rotated by a spindle motor 23, and transducer heads 27 moved radially across the data disks 29 by one or more actuators 37 for writing data to and reading data from the data disks 29.

Referring to FIGS. 2-3, in one embodiment, the drive controller electronics 26 of FIG. 1 includes a data controller 30 interconnected to a servo controller 34 via a bus 31, and a read/write channel 32 interconnected to the data controller 30 via a data buffer bus 33. The read/write channel 32 and the servo controller are connected to a read the HDA 28, and specifically, in one version, to a data transfer driver comprising a preamplifier/head-select/write driver circuit 11 (preamplifier/circuit 11) in the HDA 28.

One function of the preamplifier/write driver 11 is to preamplify the electrical signals transduced from the recorded flux transitions on the surfaces 98 of the disks 29 during reading via heads 27, and to amplify the driving current for writing data to the surfaces 98 of the disks 29 during data writing operations via heads 27. Further, the circuit 11 selects the transducer head(s) 27 for read/writing data as described further below.

A typical data write operation initiated by the CPU 14 (FIG. 1) to the disk drive 25 may involve, for example, a direct memory access ("DMA") transfer of digital data from the memory 16 onto the system bus 20. Data from the system bus 20 is transferred by the I/O adapter 18 onto the I/O bus 22. The data is read from the I/O bus 22 by the data controller 30, which formats the data into data segments with the appropriate header information and transfers the data to the read/write channel 32. The read/write channel 32 operates in a conventional manner to convert data between the digital form used by the data controller 30 and the analog form suitable for writing to data disks by transducers 27 in the HDA 28 selected by the preamplifier circuit 11.

For a typical read request to transfer data segments from the HDA 28 to the CPU 14, the data controller 30 provides a disk track location to the servo controller 34 where the requested data segments are stored. In a seek operation, the servo controller 34 provides control signals to the HDA 28 for commanding an actuator 37 to position a transducer 27 over said disk track for reading the requested data segments therefrom. Data read from the transducer 27 is preamplified in the preamplifier 11, and the read/write channel 32 converts the analog data signals from the preamplifier 11 into digital data and transfers the data to the data controller 30. The data controller 30 places the digital data on the I/O bus 22, wherein the I/O adapter 18 reads the data from the I/O bus 22 and transfers the data to the memory 16 via the system bus 20 for access by the CPU 14.

In one example, the surfaces 98 of data disks 29 include head positioning servo patterns, wherein for servo operations, head positioning information from data disks 29 are induced into the transducers 27, converted from analog signals to digital data in the read/write channel 32, and transferred to the servo controller 34, wherein the servo controller 34 utilizes the head positioning information for performing seek and tracking operations of the transducers 27 over tracks on disks 29. In another example described further below (FIG. 7), the disks 29 do not include servo patterns, and the disk drive 25 includes a reference disk 76 having reference patterns thereon which are utilized in a self-servo writing process according to an aspect of the present invention to write servo patterns on the disks 29.

FIG. 3 shows an example block diagram of an embodiment of the circuit 11. In this embodiment, the circuit 11 includes at least one control interface comprising e.g. registers 36 for receiving and maintaining information (e.g., configuration information) transmitted to the circuit 11 from an external source such as the data controller 30, the channel 32 and/or the servo controller 34. The configuration information is used to selectively configure the operation of the circuit 11, including head selection and data transfer operation modes (e.g., via mode control bits) described below. In one example, the configuration information includes mode select information such as e.g. data transfer and head select control signals.

The example circuit 11 further includes head interfaces comprising at least a read circuit 38 and at least a write circuit 40, wherein in one embodiment of the circuit 11 the read circuit 38 can be connected to a selected one of multiple heads 27 by a multiplexer function, and similarly the write circuit 40 can be connected to a selected one of multiple heads 27 by a multiplexer function. In other example versions of the circuit 11 shown in FIGS. 4-5, and described below, the circuit 11 includes a read circuit 38 and a write circuit 40 for each transducer head 27, to write data and read data, respectively. The circuit 11 further includes a mode control 41 (e.g., register or multiplexer) to provide control signals to the read and write circuits 38, 40 based on data transfer mode select information provided by the controller 34 to the register 36 of the circuit 11 for selecting one or more heads 27 for read/write operations via the read and write circuits 38, 40, respectively. Further, the mode controller 41 emits control signals to e.g. read and write cricuits 38, 40 and heads 27 to ascertain their individual operating modes at any given time.

In one example embodiment, each read circuit 38 comprises a tri-state differential receiver and buffer, and each write circuit 40 comprises a tri-state differential driver and buffer. Data to be written is provided to each write circuit 40 along data lines 42. Preferably, a pair of lines 42 provide data to each write circuit 40, wherein both lines 42 carry the same signal, but each line 42 is inverted with regard to the other to provide noise immunity. In one version, each head 27 includes a reader element and a writer element, each writer element connected to output of a respective write circuit 40 via lines/nodes 44. Similarly, for each read circuit 38, a pair of read data lines 46 provide data signal read from the heads 27, wherein each line 46 is inverted with respect to the other line 46 to provide noise immunity. The input of each read circuit 38 is connected to a reader element of a respective head 27 via lines/nodes 48.

The data read by a head 27 passes through the preamplifier circuit 11 which also provides head selection and write driving functions during data write operations. As shown in the example FIG. 4, the circuit 11 enables four separate heads 27 to be individually

selected. Based on the information in the registers 36, the mode control 41 enables the circuit 11 to provide several functional/operational modes including: (1) Write Mode, (2) Read Mode, (3) Servowrite Mode and (4) Read While Write, or simultaneous read and write, ("RWW") mode. In one example, the mode control 41 comprises a multiplexer wherein at least the registers 36 provide selection signals to the multiplexer 41, whereby the multiplexer 41 generates control output signals for selecting/enabling the read and write circuits 38, 40 of the circuit 11, and transducer heads 27, according to the present invention.

In the Write Mode, the circuit 11 provides functions including receiving data transmitted to write data inputs 50 of the circuit 11 by e.g. the read/write channel 32 (or the controller 34) and recording the received data to a surface 98 of a disk 29 using at least one selected write circuit 40 and a corresponding head 27 in a write operation.

In the Read Mode, the circuit 11 provides functions including receiving signals sensed by at least one selected head 27 via a read circuit 38, at read data outputs 52 of the circuit 11. In a typical read/write operation, a single head 27 is selected by the mode control 41 according to head selection information received by the registers 36 (e.g., serial interface (SIF) registers) from the read/write channel 32 (or the controller 34). In one example, the circuit 11 utilizes an external state signal (e.g., serial word) from the read/write channel 32, providing the state of each head on an external pin 54 (R/-W), wherein the head state information includes whether a selected head 27 is in read or write mode (e.g., R/-W hi indicates read mode, whereas R/-W low indicates write mode). The mode control 41 in circuit 11 utilizes the head state information to change the state of a selected head 27 as necessary based on the required read/write operation.

In the Servowrite Mode, the circuit 11 provides functions including receiving data transmitted to the write data inputs 50, and recording the received data to one or more surfaces 98 using one or more selected write circuits 40 and one or more corresponding heads 27 in a write operation. In one version, servowrite mode is accomplished by the mode control 41 enabling the writer element of multiple heads 27 simultaneously, wherein the

same input data from the write data inputs 50 are sent to multiple heads 27 for writing at the same time or in overlapping form. In this case, reader elements of multiple heads 27 are not enabled at the same time because read and write functions are gated by the state of R/-W signal, and the read and write functions can only be mutually exclusive.

In the Read-While-Write (RWW) mode the circuit 11 provides functions including simultaneously: (1) receiving signals sensed by at least one selected head 27 at read inputs of a corresponding read circuit 38, processing the signal within the read circuit 38, and outputting the read data at the read data outputs 52 of the circuit 11, and (2) receiving data transmitted to write data inputs 50 of the circuit 11, processing the write data signals within one or more selected write circuits 40, and recording data output from the selected write circuits 40 to a surfaces 98 of one or more disks 29 using one or more corresponding heads 27 in a write operation.

In one RWW example, at least one head 27 and corresponding read circuit 38 are selected for a read operation, and at least another head 27 and corresponding write circuit 40 are selected for a write operation. In another RWW example, the same head 27 and corresponding read and write circuits 38, 40 are selected for simultaneous read and write operations using that one selected head 27. Other examples are possible, such as, the mode control 41 can select a single read circuit 38 to supply output signals read from a disk surface 98 by a corresponding head 27 to the read data outputs 52, while simultaneously selecting one or more write circuits 40 for writing data to one or more disk surfaces 98 via corresponding heads 27. As such, the circuit 11 outputs a signal read by a head 27 via a corresponding read circuit 38, while servowrite mode is in effect (e.g., servowrite mode enabled and R/-W is low), wherein data is written via one or more selected write circuits 40 and corresponding heads 27. Each of the circuits 38, 40 can include additional components for further processing of read/write signals.

In one embodiment, the mode control 41 comprises a multiplexer circuit (Mode Control Mux) providing control signals via control lines 56, 58 to the read and write circuits

38, 40, respectively, based on the information in the registers 36. The circuit 11 includes a control line 56 for each read circuit 38, and a control line 58 for each write circuit 58. The model control 41 controls (e.g., enable/disable) the read and write circuits 38, 40. In one RWW scenario, to read data, the mode control 41 enables a selected read circuit 38 and corresponding head 27, and disables the remaining read circuits 38 in the circuit 11 to prevent simultaneous transfer of data from more than read circuit 38 to the read data outputs 52 of the circuit 11.

Utilizing enable/disable is an example form of write control and read control. Write control and read control can be used in combination with enable and disable controls. A control register controls the head read bias to control read. As such, the control of the reader portion of a head 27 for RWW can be controlled by e.g. one or more of the following: Bias Enable (Controller flips the bit); Reader Mux select/deselect; Read driver 38 enable/disable.

To write data, the mode control 41 enables one or more selected write circuits 40 and corresponding heads 27 for writing data. For example, the circuit 11 provides Servowrite Mode by enabling a plurality of selected write circuits 40 and corresponding heads 27 simultaneously, wherein the same data from the write data inputs 50 of the circuit 11 is provided to each enabled write circuit 40 for recording a plurality of disk surfaces 98 by a plurality of corresponding heads 27.

In one implementation, the registers 36 comprise a read head select register 60, a control register 62, and a write head select register 64. The circuit 11 provides independent control of read and write circuits 38, 40 and corresponding heads 27 using the serial encoded control register 62. Based on the information in the control register 62, the mode control 41 enables or disables different task related modes (data transfer modes) where reading and writing combinations are different (e.g., Read Mode, Write Mode, Servowrite Mode, RWW Mode, etc). In one example, data transfer mode select information is provided by the controller 34 to the control register 62 of the circuit 11 for selecting one or more heads

27 for read/write operations via the read and write circuits 38, 40, respectively.

The head select registers 60, 64 store information for the mode control 41 to select one or more heads 27 for read and/or write operations, respectively. The control register 62 is used in conjunction with read and write head select registers 60, 64, whereby through coordination of aforementioned modes, and read/write circuit and head selections, the circuit 11 provides the disk drive 25 with the capability to perform functions not previously possible or cost-efficient. Such functions include self-servowriting, self-reprocessing, negating disk flapping when writing data fields, track-centering while writing (for dual actuator), calculating position error before head switches (single actuator), etc..

Referring to FIG. 5, in one RWW mode example, a control bit in the control register 62 signals the mode control 41 to place the circuit 11 in the Servowrite Mode. Another set of bits in the control register 62 act as an adjunct head select register, wherein based on the write head select register 64, the mode control 41 selects a pair of heads 27 for writing in Write Mode, leaving the read head select register 60 to select a head 27 to simultaneously read in Read Mode. For example, a processor 110 in the servo controller 34 (FIG. 3) provides mode select information to the mode control 41. In one case, pre-programmed mode information is stored in the memory 305 which is utilized by the processor 110 to specify selection of particular read and write circuits 38, 40. The mode information is communicated from the processor 110 via a serial data interface 303 in the controller 34, to the serial control register 62 and written to the read and write head select registers 60 and 64. Based on the mode information, the mode control 41 provides control signals 56, 58 to the read and write circuits 38, 40, respectively, to allow e.g. a single selected read circuit 38 to read data via a head 27 and supply an output signal to the read data output 52 of the circuit 11, while simultaneously selecting one or more write circuits 40 to write data from input 50 via one or more corresponding heads 27. In one example, the controller 41 further utilizes the state of the heads 27 for head selection (i.e. R/-W signal) described above.

As such in Servowrite Mode (i.e. servowrite mode enabled and R/-W is low), the

circuit 11 processes an output signal from a read circuit 38. Further, an additional control bit in the mode control 41 prevents the read data path 46 from being disabled during the Servowrite Mode write operation (i.e. R/-W low) thus e.g. allowing reading of servo information while writing data, to be used in the normal drive operation for radial and circumferential positioning of the heads.

In another scenario, the circuit 11 performs the RWW function for the Read Mode and the Write Mode (in addition to that in the Servowrite Mode), wherein the control 41 provides control signals to the read and write circuits 38, 40 to read and write to the same head 27 simultaneously. Further, the circuit 11 can provide control signals to the read and write circuits 38, 40 for simultaneously: (1) receiving signals sensed by a plurality of selected heads 27 at inputs corresponding to selected read circuits 38, and transmitting the read data at the read data outputs 52 of the circuit 11, and (2) receiving data transmitted to write data inputs of a plurality of the circuits 40 for recording to a plurality of surfaces 98 using a plurality of corresponding selected heads 27 in a write operation. In one version, at least one head 27 is selected for a read operation, and at least another head 27 is selected for a write operation simultaneously. In another version, the same head 27 is selected for simultaneous read and write operations.

The read channel circuitry can be modified to be independently selectable to be active or inactive during the write function, providing: (1) independent operation of the write and read paths through the read channel device, (2) support for simultaneous read and write data streams from the disk controller portion of the ASIC, and (3) redefined ASIC-Read channel interface.

The circuit 11 can be utilized in place of conventional read/write preamplifiers in many mass storage devices such as, but not limited to, hard disk drives. The RWW function of the circuit 11 provides the ability to independently select the read and write functions/operations utilizing e.g. read and write circuits 38, 40, such that read and write circuits 38, 40 can be selected to operate separately or together (e.g., simultaneously). The RWW function

enhances existing capabilities of disk drives, and improves processing and performance. Further, the RWW function provides cost-effective versatility that can not be duplicated with a single IC conventional preamplifier.

In one example, a disk drive 25 including the circuit 11 provides self-servo write with absolute referencing that a servowriter offers. The disk drive 25 includes the ability to stagger or bank write by reading real-time position and timing information while writing servo patterns. The circuit 11 provides such capability by allowing reading a reference pattern from a reference surface of a disk using one selected head while writing servo patterns on one or more blank disk surfaces using one or more selected heads, simultaneously. For example, one head 27 is selected for reading a reference pattern for providing position and fundamental timing information for servo patterns to be written simultaneously on an adjacent head or heads. Many methods of self-servowriting can be adapted to be more efficient and more accurate using the circuit 11. A few examples of improved self-servo-writing according to the present invention are described below. Other examples are possible and are contemplated by the present invention.

One such method is read-while-write self-servo-write using a reference disk. This method of self-servowriting incorporates the use of e.g. a magnetic printed media surface that includes both timing and radial position information (self-servo patterns). FIG. 6 shows a highly diagrammatic representation of an embodiment of a magnetic printing station for printing a reference disk storage surface with a servo reference pattern. a magnetic printing station 70 magnetically prints or otherwise transfers a servo reference pattern 72 to one surface 74 of a magnetic disk 76, known as a reference disk.

The magnetic printing station 70 can utilize one of several known magnetic transfer processes. One such process includes the steps of applying a unidirectional magnetic domain orientation to a blank storage disk, such as the surface 74 of the disk 76. Then, a reticle or magnetic die having the desired magnetic reference pattern is placed into close proximity with the storage surface 74 of the disk 76, and the disk 76 is heated to approach the Curie temperature of the storage media on the surface 74. The reference surface 74 is

selectively remagnetized with the aid of a reverse bias field and e.g. localized heating in accordance with the reference pattern established by the reticle or die.

In cases where an optical reticle is used, intense local heating through reticle apertures can be obtained from a laser beam, for example, in accordance with well understood magneto-optical principles in order to provide selective magnetization of domains of the reference-patterned surface 74 in accordance with the servo reference pattern 72. Care must be taken during the magnetic printing process not to damage or contaminate the disk 76. Preferably, although not necessarily, the magnetic printing process is carried out in a very clean environment within a disk manufacturing process.

The reference disk 76 is placed in a disk stack, and is used to recalibrate timing and position before each servo write. Referring to FIG. 7, after the servo reference pattern 72 has been applied to storage surface 74 of the printed disk 76, the disk 76, along with other blank disks 29 are assembled onto a spindle 80 of a disk drive 25. The spindle 80 is mounted within an enclosed head-disk assembly (HDA) 28, and is rotated at a predetermined angular velocity by a spindle motor 23. A comb-like head actuator structure 37 is included with the HDA 28, wherein the head actuator structure 37 includes head arms 90 rotated by e.g. a rotary voice coil motor 92 in order to position transducer heads 27, respectively, adjacent to the reference surface 74 of the disk 76 and blank surfaces 98 of the disks 29.

After the disks 76, 29 and heads 27 are installed, the HDA 28 is enclosed by a cover to prevent unwanted particulate contamination. A drive controller electronics module 26, such as a printed circuit board carrying large scale integrated circuits and other components, is mechanically attached to the HDA 28 and electrically connected thereto by a suitable interconnection 102, in order to complete the assembly of the disk drive 25. The disk drive 25 is then placed into a self-scan chamber 104 and connected to a suitable power supply, wherein a control and status collection computer (not shown) collects data concerning the disk drive 25 during self-scan procedures.

In one version of the present invention, a special program in the drive controller electronics 26 (e.g., resident in memory 305 (FIG. 3) or downloaded from a status collection computer) enables a head 27 to read the reference pattern 72, and in turn enables one or more other heads 27 to write precise servo patterns on each storage surfaces 98 in accordance with a final servo pattern features plan. After all of the surfaces 98 of the disks 29 have been written with final servo patterns, the reference pattern 72 is overwritten, either in the self-scan station 104, or later with user data when the disk drive 25 is installed in a user computing environment for data storage and retrieval operations.

Referring to FIG. 8 in conjunction with FIG. 7, in a self-servo writing method using the drive controller electronics 26 including an embodiment of said circuit 11, the timing and position information of reference pattern 72 is read from the reference disk 76 via one head 27 and the information is processed by: (1) a position control process executed by the processor 110 and (2) a pattern generator process 112 , (e.g., instructions stored in memory 305) within the drive controller electronics 26. Simultaneous with reading the reference pattern 72 from the reference disk 76 via a selected head 27, a servo pattern is written to surfaces 98 of one or more other disks 29 via one or more other heads 27 under control of a servo write process executed by the processor 110, thereby generating cohesive cylindrical timing/servo wedges on the other disks 29. In FIG. 8, a head 27 is utilized per disk surface (designated as heads 27_x to indicate multiple heads 27 in FIG. 8, wherein 'x' is a head index).

The method provides self-servo writing with absolute radial and circumferential referencing of conventional servowriters, but without disadvantages of the conventional servowriters. The disk drive 25 staggers or bank writes the servo patterns on surfaces 98 of disks 29 using real-time position and timing information from the reference disk 76 during the servo write process. The circuit 11 allows reading timing/position information 72 from the reference disk 76 on one head 27 while simultaneously writing servo patterns on surfaces 98 of one or more disks 29 using one or more other heads 27.

Specifically, in one example, in self servowrite using RWW mode, the circuit 11 is configured by information transmitted to the registers 60, 62, 64 therein, for the mode control 41 to select and enable: (1) one read circuit 38 in Read Mode to read the reference pattern 72 via a corresponding read head 27, and (2) one or more write circuits 40 are selected for Write Mode (or alternatively Servowrite Mode) to write a servo pattern on surfaces 98 one or more disks 29 via one or more selected heads 27.

Head selection via register 60 is performed to select a read head 27, and Servowrite Mode selection via register 64 is performed to select one or more write heads 27 for writing servo patterns, whereby effectively the read head 27 is mapped out from writing during self-servo write operation. This allows the read head 27 to read the reference pattern 72 from the disk 76 and provide the timing and position information back to the disk drive controller electronics 26 for processing, and simultaneously writing servo patterns on surfaces 98 of disks 29 via write heads 27, without disturbances from the writer elements of the dedicated read head 27. In this way, the drive controller electronics 26 can clock out the servo pattern on one or more disks 29 in the same manner as a clock track.

The reader element of the read head 27 reads the reference pattern 72, and provides a read head signal 114 to the read/write channel 32 (including an AGC/Filter circuit 304, servo demodulator 306 and pulse detector 308). In the self-servowrite RWW mode, the read/write channel 32 utilizes the read signal 114, and resolves timing information 114A and position information 114C (periodically) from the read signal 114. The read/write channel 32 decodes position information 114C and timing information 114A from the reference pattern 72 by e.g. either amplitude (i.e., standard burst demodulation) or interval (i.e., phase angle position) to hold accurate head placement and simultaneously write servo patterns to the disks 29 using write heads 27. In this way, the disk drive 25 in effect functions equivalent to a servowriter. In another version, disk drive firmware comprising programmed logic or control instructions (e.g., resident in memory 305 in FIG. 3) resolves the read signal 114 into the position and timing signals 114C and 114A, respectively. Other versions are possible and

contemplated by the present invention.

In either case, after servo patterns are written to the disks 29, the read head 27 can be selected in Write Mode to overwrite the reference pattern 72 on disk 76 with a servo pattern such that the disk 76 can be used for storing user data. Preferably, at least two circuits 38 and/or 40 are selectable in the RWW mode such that the reference surface 74 of reference disk 76 can be overwritten in the same manner after the servo pattern has been recorded to the other disk 29.

Unlike the present invention, conventional self-servo write processes do not provide for multiple tasking in reading a reference pattern 72 from a disk 76 while writing servo patterns on one or more disks 29. Conventionally, reading a reference pattern 72 from the disk surface 74 via a read head 27 is sequentially followed by switching to other heads 27 to write a servo pattern on an disk 29, wherein the read and write operations are mutually exclusive (i.e., not overlapping or simultaneous). As such conventionally, the reference pattern 72 is read for a time period via one head 27 to obtain timing and head position information, and for a following time period the timing and position information is utilized to position another head 27 and write the servo pattern on a disk 29 (e.g., a wedge). The conventional self-servo write process switches between reading and writing until the entire servo pattern is written out on a disk 29.

By contrast, in a self-servo write using RWW process according to the present invention, there is no need to switch out of the reference pattern 72 Read Mode to write servo patterns on disks 29. As such, the reference information (e.g., timing and position information 114A, 114C, respectively) obtained from the read signal 114 from the reference disk 76 via one head 27 are used to simultaneously clock out servo patterns to other disks 29 on other heads 27. Further, any timing errors (e.g., due to rotation speed variations) are compensated for in real-time. The disk drive 25 accounts for rotation speed variations by correcting timing errors while a servo pattern is being written, to efficiently generate an accurate servo pattern, without need for repeating servo writes due to e.g. timing/speed

variations between reference read servo and write operations which negatively affect said conventional methods.

In self-servo-write method, the circuit 11 is configured by information transmitted to the registers 36 therein, to select e.g. read circuit 38 and corresponding head 27 for reading timing and position information (i.e., Read Signal 114) from the reference surface 74 of the reference disk 76. The reference information provides head position and timing information to the servo controller 34 (FIG. 3) for positioning write heads 27 as necessary for writing servo patterns. Said position and timing information are processed by the write clock pattern generator process 112 and the servo/position control processor 110 within the drive controller electronics 26 (e.g., servo controller 34). For writing servo patterns, head positioning information 116 is generated by the servo processor 110, and servo pattern information 118 is provided by the pattern generator process 112.

The RWW preamplifier circuit 11 enables real-time and/or ultra high bandwidth closed loop operation (e.g., for self-servo write) that can not be accomplished with a conventional drive preamplifier. Referring to FIGS. 9A-B, an example process for self-servo write using a printed media reference pattern is described. The process controls the orientation of magnetic domains to create a final servo pattern that is concentrically and radially arranged on a magnetic recording surface 98 that is typically used in the manufacture of hard disk drives. The final servo pattern includes position and timing information that is used by the drive mechanical, electrical and control system to establish absolute radial and circumfrential placement of its transducer heads.

As described above in relation to FIGS. 6-7, creating a printed media reference surface 74 (step 200) can be accomplished in several ways. One example is to place a mask onto a magnetic surface that has all of its domains oriented in one direction. The mask is made of magnetic shielding material and is affixed to a surface of the media disk 76. A magnet of opposing orientation is passed over the masked surface of the media, and causes the unmasked areas of the media to invert their orientation. The domain orientation

differences are read by a transducer head as flux transitions, and are used in a drive for timing and amplitude metrics. The reference disk 76 is installed into the disk drive 25 during the assembly process (step 202) and drive controller electronics 26 included therein (step 204). When the drive assembly is complete, the drive 25 is installed into a self-scan chamber 104 (step 206) that provides a stable mounting structure, thermal stability, power and an interface buss that can be connected to a PC for loading a test process firmware into the drive 25.

After the disk drive 25 is powered up (step 208) and spins up (step 210) to a programmed/desired rotational speed (steps 212, 214), the self-servowrite process can begin (step 216). The self-servo write process is controlled by the processor 110. Registers 35 in the controller 34 are setup to contain information for the processor 110 to use for the self-servowrite process. The registers 35 are loaded with the number of spokes, number of heads, length of reference spokes, number of transfer fields, length of transfer fields, head width, total number of tracks, and other pertinent information to complete the process. In one example, the self-servo write process is executed by the processor 110 from instructions (e.g., firmware) resident in a memory/ROM 305 (step 218), as follows. The heads 27 are moved to position a head 27 over the reference pattern 72 (step 220) and based on control/configuration signals from the processor 110, the control 41 places the circuit 11 in normal Read Mode (described above) (step 222). Accordingly, the control 41 enables a transducer head 27 that corresponds to the printed media surface 74 (step 224), and the reference information 72 is read via the selected read head 27 to generate the read signal 114.

FIG. 10A shows an example of servo position information composite of the reference pattern 72 on the reference surface 74. The reference pattern 72 includes a plurality of concentric tracks, each including reference spokes 122 with a multiplicity of transfer fields 124 therebetween. The reference spokes 122 in concentric tracks form radial spokes. The FIG. 10A example shows several transfer fields 124 between two reference spokes 122. Each reference spoke 122 includes gray code (I), and servo burst quadrature pattern (II) of

servo bursts A, B, C and D. The gray code is a binary-like coding system that is part of the reference pattern 72 and contains coarse position information, and the amplitudes of servo bursts A, B, C and D provide fine head position information. Each transfer field 124 includes servo burst pesudo-quadature pattern (III) A1, B1, for on track head positioning. FIG. 10C shows further details of spokes 122 and transfer fields 124, providing position and timing information (e.g., transfer timing). In another example there can be on transfer field 124 between a pair of spokes 122, wherein the transfer field includes multiple pairs of servo burst pseudo-quadrature patterns A1, B1.

Referring to FIG. 10B, the position and timing information in reference pattern 72 induces the read signal 114 in the read head 72, wherein as described above the read signal 114 includes the position signal 114C and the timing signal 114A. The A/D circuit (servo demode) 306 in the channel 32 resolves the position information signal 114C and the timing information signal 114A from the read signal 114. The position control processor 110 uses the position information 114C as it is read by the selected head/sensor 27 from the reference pattern 72, as feedback during the RWW self-servowrite process to determine the current head position. The current head position is then subtracted from the desired head position by the processor 110 and a position *command* is issued based on the difference. The position *command* is output through a servo control interface 302 as digital position data 116 and is converted to an analog signal in the power electronics driver 119 which drives the VCM 92 in the HDA 28. This method is utilized during self-servo writing to maintain accurate position control of the write head 27 over the disk surface 29.

Referring back to FIGS. 9A-B, the servo processor 110 waits for a pattern sequence that initiates a servo lock attempt. If the data that follows is what is expected, an initial lock is complete, and absolute position is attempted to be acquired by reading the gray coded region of the reference spoke 122 (FIGS.10A, 10C, 'Cyl. #') (step 226). Once the absolute position is acquired, the position control loop (e.g., FIGS. 10A-B) (step 228) is commanded to move a write transducer head to the 'start servowrite' position on at least one disk surface 98 for writing final servo patterns thereon (steps 230, 232).

FIG. 11 shows an example diagram for generating a final servo pattern signal 118. Referring to FIGS. 9A-B in conjunction with FIG. 11, when the transducer 27 is stabilized over the starting position on at least a disk surface 98, the pattern generator 112 (FIG. 11) loads a 'final servo pattern' (e.g. from a memory 39) into a shift register 126 as a series of 1's and 0's (step 234), and the pattern generation sequence begins. The clock multiplier PLL 111 is phase locked to the signal 114A (the timing frequency of the transfer field 124 in FIG. 10C) (steps 236, 238). Thereafter, in response to configuration signals from the processor 110, the control 41 sets write currents for write heads 27 (step 240), and selects write heads 27 for writing the servo pattern 118 on disk surfaces 98 (register 64, FIG. 2) (step 242). The control 41 selects RWW Mode for the circuit 11 (step 244), and self servo write pattern is synchronized with reference spoke index 122 (steps 246, 248). A spoke counter is loaded with the number of spokes 122 per revolution of disk 76 (step 250). When the read head reaches the end of a reference spoke 122 (step 252), the selected write head 27 is enabled (step 254), a transfer field counter (e.g., within registers 35) is loaded with the number of transfer fields 124 between each pair of reference spokes 122 in the pattern 72 (step 256), and the read transducer reads a transfer field in the reference pattern 72 (step 258).

The servo positioning according to FIGS. 10A-B operates in overlap or simultaneous mode with the pattern generation and write operation according to FIG. 11. Servo positioning by processor 110 is accomplished by reading and processing the amplitude of the A1 and B1 servo bursts of the transfer pattern 72 as shown in FIGS. 10A-B. The A1 and B1 bursts are used only for on-track center maintenance between the reference spokes 122. The reference spokes 122 include absolute position information (i.e. gray code and four burst quadrature), and are used for track to track positioning. Pattern generation is accomplished per example of FIG. 11 and can be traced through using the signal 114. The timing signal 114A is used for pattern generation (e.g., FIG. 11), and the position signal 114C is used for servo positioning (e.g., FIGS. 3, 10B and 11).

Referring back to FIGS. 9A-B, an example servo positioning and parallel/overlapping

pattern generation and servo write process as controlled by the processor 110 is described. After reading a transfer field 124 in step 258, in a servo positioning process, the read head 27 is maintained on track center of a transfer field (step 260) by reading and processing the amplitude of the A1 and B1 servo bursts of the transfer pattern as shown in FIGS 10A-B, wherein A1 and B1 are used for on-track center maintenance between the reference spokes. The difference between read head sensed amplitude of A1 and B1 (A1-B1) is measured (step 262), wherein if the difference A1-B1 is not zero, then the head position is adjusted (step 264). The steps 262, 264 are repeated to maintain the head on track center of the transfer field. Once the head is on track center, the gray code in the reference spoke is read (step 276) and a determination is made if the head is on the proper track number (step 278). If so, the spoke counter is decremented by one (step 280), wherein when the spoke counter shows zero, indicating that all spokes on the current track have been processed (step 282), the head is moved to the next radial track position (step 284). To process the remaining tracks of the reference pattern 72, the positioning process proceeds to step 246.

In a simultaneous or overlapping pattern generation and servo write process under control of the processor 110, after reading each transfer field 124 from the disk 76 and positioning of the read and write heads, a corresponding final servo pattern 118 is written on each disk surface 98 via a corresponding write head. Specifically, each transfer field is read from the disk 76 via a read head (step 258), a corresponding final servo pattern is written via a selected write head on a disk surface 98 (steps 266, 268), the process selects the next write head in sequence for the next surface 98 of a disk (step 270), decrements the transfer field counter by one (step 272), and if the transfer field counter is not zero (step 274), the process proceeds back to step 258 for reading the next transfer field and writing a final servo spoke 128 (in servo pattern 118) using said next selected write head to a corresponding disk surface 98. Steps 258 through 274 are repeated in a loop for all transfer fields 124 between each pair of reference spokes 122. Once all transfer fields 124 between a pair of reference spokes 122 have been so processed, the pattern generation and servo write process proceeds to step 276 for processing remaining reference spokes on the current track of the reference pattern 72.

In the example pattern generation process of FIG. 11, once the index reference spoke 122 is detected and the first transfer field begins, the clock multiplier 111 'out' is enabled. The read signal 114 via circuit 11 is processed by channel 32 (AGC 304 and pulse detect 308) to generate the timing signal 114A for the clocking the serial shift register 126. The pattern of 1's and 0's from the register 126 is processed by the preamplifier circuit 11 to control the direction of current through the selected 'write' transducer heads. The current through a transducer head is changed from one direction to the other causing the polarity of the media magnetic domains to change within the effective field. The series of transitions on each surface 98 are the final product spoke 128 (this process is graphically depicted as the closed loop operation in FIG 11). In this example, the final spokes 128 are placed onto different disk surfaces 98 in a stagger pattern depicted by example in FIG. 12, wherein the disk assembly comprises a reference disk 76 and three data disks 29, the reference disk having a reference surface and a blank surface 98, and each of the three data disks having two opposing blank surfaces 98. Each disk surface has a corresponding head 27 (total of eight heads). In the example of FIG. 12, a read head 27 (e.g., HDn) is positioned to read the reference pattern 72 from disk 76, and each of a plurality of write heads 27 (e.g., HDn+1 through HDn+7) is positioned to write final servo patterns on a surface 98 of a disk 29. There are seven transfer fields between each pair of reference spokes in the reference pattern 72, and steps 258-274 are repeated for each transfer field. This process is repeated for all tracks until all of the tracks are written across the surfaces of disks 29. In another example the final servo spokes 128 are placed onto different disk surfaces 98 in a bank write.

Once all tracks of the reference pattern 72 have been processed (step 286), a self-scan process (step 288) begins as described further below. If in step 278 the head is not on the proper track number, the servo positioning process proceeds back to step 230 to move the head(s) to proper start position. If in step 282 all the spokes and transfer fields for the current track have not been processed, the positioning process proceeds to step 252 to process the next spoke.

As such, referring to FIGS. 8, 10A-C and 11, the position control processor 110 and the clock and pattern generation process (circuit) 112 allow dissection of the reference information 72 read from the reference disk 76 to select the portion of reference pattern data to analyze (e.g., position/timing information). In one embodiment, the position control process comprises a logic circuit implemented in an ASIC or a process executed by processors (e.g., processor 110) within the controller ASIC 34 of the drive controller electronics 26. Position is maintained by servo-burst equalization shown by example in FIGS. 10A-B. Any timing errors are erased and rewritten until they are within acceptable tolerance, such that timing remains coherent across entire surface 98. The reference read frequency is phase locked to the pattern generator clocking frequency thus keeping the servo pattern synchronously locked to the rotational speed variations caused by the spindle motor control error (e.g., FIG. 11). The clock signal 114A provides the timing for the clock multiply circuit 111 which provides the timing and frequency for the pattern generator circuit 112. The process/circuit 112 under firmware control generates the servo pattern data 118. Because the read reference signal 114 is read simultaneously while writing final servo patterns, the servo pattern data 118 written to each surface 98 is synchronized to the rotational speed of the disks 29. The relationship between signals 114 and 118 is closed loop due to the RWW function of the circuit 11.

Disk flapping modes (i.e. mechanical distortions to a flat disk surface caused by rotational and axial excitation) can cause unwanted disturbances. RWW according to the present invention can take advantage of the spoke stagger (sequential spoke offset from one surface to the next) from head to head. Specifically, for each disk having two opposing surfaces 98 and two corresponding heads 27, a position error can be updated when a head 27 is writing on one surface, by reading the servo information on the opposite disk surface 98. The radial movement detected by the opposite head is the inverse of the other head. This information can be used for write-position correction, or as a write error detection. Further track centering on one head while writing on another can be performed actively.

Further, self-servowriting using magneto-resistive type transducer (MR) including a

writer element and a reader element, is made simpler by the present invention because it is not necessary to compensate for the reader element offset from the writer element in the same head 27. The dedicated read signal from a read head 27 is a relative reference for radial position, and an absolute reference for timing because timing is coherent from track to track. Position ultimately depends on each head's physical placement over the corresponding disk surface. The disk surface provides a relative reference in the same way that a servowriter uses an external reference to establish the radial location of the heads 27. The offset difference between the final product servo wedges/spokes and the reference surface need only be compensated for during the reference-overwrite process. Once the tracks are placed, the transfer fields on the reference surface are transferred to obtain the product servo wedges in an absolute reference to the other tracks. However, due to the reader/writer element offset in a head, if a track is copied from a new reference track, the track is placed relative to the writer elements location which would slightly shift or offset the track location relative to the rest of the cylinders, thereby necessitating compensation. This offset can be reconciled during the reference surface overwrite process (reprocess) with a geometry normalization table or algorithm which accounts for the offset difference of absolute track placement due to use of the new reference surface and the physical reader/writer element offset difference of the head 27. For an example track density said offset can be more than 10 tracks.

In another aspect, the present invention provides a referenced media translation self-servo writing method. The disk drive assembly includes at least one reference disk with a reference surface having a reference pattern including fundamental timing (e.g., clock frequency) and position information. In a method different from the printed media reference disk above (FIG. 6), the reference pattern 72 is written on the surface 74 of the reference disk 76 e.g. using a spin stand writer. Thereafter, the media translation self-servo writing process using RWW circuit 11 according to the present invention is similar to that for a printed media reference disk described above for in relation to FIGS. 9A-B, 10A-C, 11, 12, and therefore is not repeated again.

The frequency of the reference pattern 72 is a multiple of the final servo pattern frequency to provide servo pattern timing. The position information can be provided using a standard modified servo/timing burst, or a time interval pattern (e.g., printed media) decoded as timing and position information. The time interval pattern provides position information using a phase tracking method rather than a burst amplitude demodulation. A time interval pattern is typically used on printed media (FIG. 6), but can also be generated using conventional head/media writing methods. In a time interval pattern, radial position is derived by equating a gap length to a radial location. There are two major fields to a time interval pattern: a Reference Field and a Chevron Field. The Reference Field includes series of radially coherent transitions that begin and end in an exact time period across the radial stroke of the transducer 27 creating a reference domain (e.g., the first domain, 'index' begins at 0(t) and ends at (t)+10 micro seconds relative to the transducer 27 as it moves in any radial direction). The Chevron Field is a series of angularly coherent transitions relative to the Reference Field, where the beginning boundary is offset in distance from the ending boundary of the Reference Field creating an angular gap between fields across the radial stroke. The gap between the first field and the second field increases across the disk in a radial direction. Thus the phase of the range of the gap, delta(t), can be resolved as radial position and tracked electronically. i.e. (t)max - (t)min = delta(t) = 360 degrees.

An example reprocess method according to the present invention, referenced above, is now described. Typically a disk drive 25 must be reprocessed if servo-written with a faulty servo pattern. Further the disk drive must be re-servo-written if the disk drive failed the final test for marginal reasons. Reprocessing is performed when a portion of the servo pattern that was written needs to be erased before a new servo pattern can be placed. The present invention provides a self-reprocess method using RWW mode for self-reprocessing, wherein e.g. an error in self-servo write process requires erasure and re-writing of erroneous servo patterns. A controlled velocity read sweep locates residual data on disk surfaces 98 and indicates where the erroneous servo patterns needed to be erased. In one case, the MR reader of head(s) 27 is used to scan the disk surface 98 by performing an estimated velocity sweep with the reader enabled. Once erroneous data is located, the amplitude of that signal

is used by the servo controller 110 to establish a position, and then that location is erased.

Conventionally reading and writing operations are mutually exclusive, and as such servo control for reprocess is performed using one head to find and assure erasure of the desired location. However, when performing head to head position referencing, the offsets between different heads have to be characterized and compensated first. The conventional process includes locating the erroneous servo pattern with a first head, switching to a second head, servoing, compensating and erasing with that second head. A disadvantage of the conventional method is that there must be servo data present for an alternate head that corresponds to the location of interest on the surface to be erased in order to properly place the erase head.

Referring to the example flow diagram in FIG. 13 for self-reprocessing according to the present invention, the start position (e.g., track) of the area (e.g., old/erroneous servo pattern) to be erased is located on at least a disk surface 98 (step 290). The circuit 11 is configured by servo processor 110, which transmits configuration information to the registers 36 of the circuit 11, such that the mode control 41 places the circuit 11 in RWW Mode (step 292), wherein a first head 27 is selected to read residual position information from a first disk surface 98 to establish transducer radial position control (step 294), while at the same time one or more heads are selected to a erase patterns on one more disk surfaces 98 in back or stagger form (step 295). Thereafter, data on first disk surface 98 is erased using the first head (step 296) and under control of the servo processor 110, the actuator moves the head to the next track location of the area to be erased (step 297), and repeats the above steps until all tracks in the erase area have been processed (step 298). In embodiments of the heads 27 comprising separate reader and writer elements (e.g., an MR head), the self-reprocess method can be utilized within the same head 27, wherein one reader element in the head 27 is utilized to read, while the write element in the head is used to simultaneously write.

In the example self-reprocess using RWW method, the read signal is not disturbed

by writing a constant current (DC erase). This is true even while reading and writing on the same head. Servo and erase are all that is needed. All data can be erased because reading can be performed by a head□s reader element in front of the same head's writer element. Where data must be detected and erased across one or more disk surfaces 98, then servo reading can be performed on one head while bank erasing (e.g., erasing a plurality of disk surfaces) on other heads. There is no need to switch continuously from writing to reading and back again, resulting in a considerable time saving in the erase process (reprocess).

As such, in one example according to the present invention, reprocessing a disk drive is performed when there is a format failure. The failure can be for many reasons, but all or part of one or more disk surfaces 98 must be erased so that the disk drive can be re-written with new final servo spokes. Conventionally, the process of erasing previously written servo spokes is performed on a servowriter where the actuator 37 is controlled using an external positioning source. When self-servowriting, the erase process is difficult because tracks are being erased, and references are disappearing with each erase. It is especially difficult to erase using all heads via a conventional preamplifier. A RWW circuit 11 according to the present invention allows signals to be read on one head while erasing disk surfaces on the same head or on or more other heads. The process of controlling the actuator location using RWW Reprocess is similar to controlling the actuator in normal drive operations. With MR type heads where reader and writer transducers are separate, it is contemplated to read and erase (erase = DC write) on the same head. This makes the reprocessing process very efficient.

The preamplifier circuit 11 can be implemented as an integrated circuit, ASIC, IC, firmware, etc.. In addition to self-servo writing and reprocess examples described herein, the circuit 11 can be used for implementing other processes and functions within a data storage drive that can benefit from the functions provided by the circuit 11. Though in the description herein the circuit 11 has been designated as a preamplifier, the functions of the circuit 11 can be implemented in other components in the HDA 28, and/or the drive

electronics 26 of the disk drive 25. Similarly, the controller 34 and the processor 110 can be implemented as an ASIC, IC or other logic circuit configured to perform the functions/processes described herein.

Providing a disk drive with the capability to read and write data simultaneously to different data storage locations according to the present invention, is advantageous from many perspectives, for example test time reduction. As density increases test time also increases, necessitating the introduction of methods that are more time efficient. The Read-While-Write (RWW) functionality allows new methods to be used that would reduce test time in test process steps by as much as 50%. In another version, the disk drive 25 can include multiple circuits 11, wherein the RWW function allows each of the multiple of circuits 11 to perform simultaneous read and write functions.

The present invention has been described in considerable detail with reference to certain preferred versions thereof; however, other versions are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.